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TOOL USE BY THE ANT, *NOVOMESSOR ALBISETOSUS* (MAYR)

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Abstract.—Soil-dropping behavior by the arid lands ants, *Novomessor albisetosus* (Mayr), is considered as an example of tool use. Soil-dropping ceases to be a general response to any nest-threatening liquid beyond a certain distance from the nest. As petri dishes of distilled water and honey water are moved farther from the nest, ants stop dropping soil in water but continue doing so in honey water. Since soil dropped in honey water is brought back to the nest, soil-dropping serves the purpose of food retrieval. Questions concerning competitive adaptations must be considered cautiously.

Alcock (1972) has provided an excellent review of tool use in feeding and proposed the following definition: "Tool-using involves the manipulation of an inanimate object, not internally manufactured, with the effect of improving the animal's efficiency in altering the position or form of some separate object" (p. 464). In what may be the first reported case of tool use in a social insect, Lin (1964–1965) described the pavement ant's (*Tetramorium caespitum*) use of soil while attacking halictine bees. Shultz (1982) enlarged on Lin's findings, and Moglich and Alpert (1979) reported similar behavior in a study of stone dropping by *Conomyrma bicolor* Wheeler to possibly interfere with *Myrmecocystus* competition.

The first study of tool use by a social insect in retrieving food was made by Fellers and Fellers (1976). Soil was placed by *Aphaenogaster* workers on jelly bait and later retrieved to the nest. They concluded that tool using may increase the ability of *Aphaenogaster* to compete directly with dominant species. A reconsideration of their findings was presented by Fowler (1982) who found that most of the tools were not retrieved, and concluded that tool use was more important in scramble competition than in direct competitive interaction. Many years before these studies Wheeler (1910) observed that many ants "throw pellets of earth or any other debris" on a "substance that they cannot remove, such as a strong-smelling liquid." He noted that liquids more frequently evoke this behavior and that it may have evolved as a way of protecting the nest against flooding.

Given this conjecture, it is not clear whether any kind of competition was involved in the tool use response of the Feller and Feller (1976) or Fowler (1982) studies or whether tool use to retrieve food was simply the coincidental outcome of a reflexive response to a moist substance, signal of a potentially nest threatening liquid. I report here on the reaction to liquids of *Novomessor albisetosus* (Mayr), an ant closely related to *Aphaenogaster,* and the distribution of "tools" within the nest.

MATERIALS AND METHODS

Laboratory. Petri dishes of honey water (one part honey to 10 parts water) were placed in the foraging arena (61 × 61 × 30 cm). Sand was collected from various parts of the nest (3 plastic boxes joined by tubes in line from the foraging arena); it was also collected from the floor of the foraging arena, midden pile, and petri dish. Sand was analyzed for carbohydrate content by using the anthrone reaction method slightly modified from that described by Scott and Melvin (1953). There were five replications of each treatment. Two other liquids—maple sap (to test a sugar solution of natural dilution) and distilled water—both with and without red food coloring, were also placed in petri dishes in the foraging arena. Petri dishes of only one liquid was available at a time, and sand was removed from the nests after each manipulation. Lastly, water was poured directly into the nest near the exit to the foraging arena.

Field. Fifteen nests of *N. albisetosus* (Mayr) were selected within a 40,000 sq m area about 1 km west of Portal, Arizona. Each was tested with both water and honey water, once during the dry and once during the rainy season. Placement of petri dishes was at various unmeasured distances for the 1st trial during the dry season. Measurements were then taken and assigned randomly to the nests for the 2nd trial, during the rainy season.

RESULTS AND DISCUSSION

Laboratory. Analysis of sugar content in sand from the nest boxes revealed the presence of sugar in increasing quantities as the sand was sampled farther from the nest entrance and closer to the brood (Fig. 1). Sand taken from the second of three nest boxes, had the highest content of sugar (550 ± 5 μg per gram of sand). This was where the queen and brood (especially feeding larvae) remained, and where chunks of sand were first deposited by returning foragers. Although larvae were sometimes found on the sand it was being fed on by workers of all ages. Sand from a stockpile within the same nest chamber, but closer to the entrance, yielded a sugar content of 482 ± 2.2 μg. Samples taken from the next location closer to the entrance, in the first chamber, had 189.7 ± 2.6 μg. The sand pile next to the nest entrance was littered with dried mealworms, dead ants and other debris that were occassionally taken out and placed on the midden heap. This had the least sugar content within the nest (121 ± 4.3 μg). Outside the nest, in the foraging arena, sand taken from the midden heap yielded 94.3 ± 16 μg. Control samples of sand taken from three places in the foraging arena revealed no detectible sugar content. A sample used as a standard for comparison, taken from the petri dish had a sugar content of 568 μg, which was close to the sugar content of sand first deposited in the nest by returning foragers. Following a significant analysis of variance of samples taken from within the nest [$F(4,20) = 3{,}775.17, P < 0.0001$], comparisons of samples by the Newman-Keuls Multiple Range Test were all significant at the 0.01 level of confidence. Apparently, as the food value of the sand declined with its sugar content it was moved closer to the nest entrance, and eventually removed to the midden pile.

Sand was dropped in both petri dishes of maple sap and distilled water. Both red colored and uncolored sand from the maple sap was eventually taken into the nest, but not sand placed in the water. Sand was also brought into the nest and deposited on the water that had been spilled into the nest. As a further indication that it was considered debris, sand taken from the pile with the least sugar content within the nest was also placed on water flooding the nest.

Because of these results the field study was conducted. The possibility that the ants were responding to any liquid, or treating the foraging arena as part of their nest,

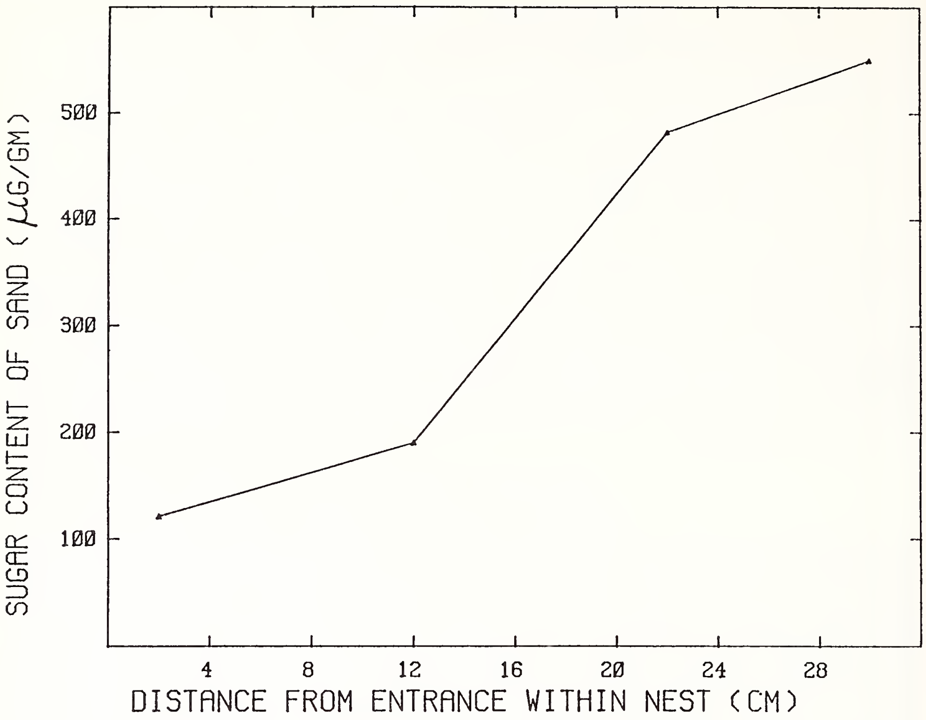

Fig. 1. The relationship between sugar content of sand and position of sand in the nest. Sand brought to the brood at a point farthest from the entrance has the highest sugar content. During stockpiling and nest maintenance, as sand is brought increasingly closer to the entrance, the sugar content of sand decreases.

hence soaking up any nest-threatening liquid with sand, could not be overlooked. Of course, this behavior itself could be viewed as tool use. However, I wanted to see if returning to the nest with sugar-coated sand was not just coincidental to the ants' dropping soil in any liquid and then discovering that the soil was sweet.

Field. The distances that water and honey water were placed from the nest entrances, both before and after the rainy season, are presented in Table 1. During the dry season soil was regularly dropped into water up to 2.13 m from the nest, though in diminishing quantities as water was placed farther from the nest. Recruitment to water was observed up to 6.1 m from the nest, through the response at this distance, 10 ants in 20 min, was about one-third the response to honey water at the same distance. No ants returned to the nest with soil (pebbles and sand) that they had dropped into the water. During the wet season (after mid-August in 1982, it usually begins early in July) soil was dropped into water up to 1.22 m from the nest but not beyond, although there was recruitment (15 ants in 30 min) up to 1.83 m from the nest. Again, no ants returned to the nest with soil from the water. The Fellers (1976) observed *Aphaenogaster* placing "tools" on jelly up to 152 cm from the nest. This is well within the 2.13 m range for dropping soil in water in the present study. What

Table 1. The occurrence of soil-dropping in and recruitment to liquid, and returning to nest with sand dropped in liquid.

Distance (m) from nest	Before rains: Water: Soil	Re-cruit	Return	Honey water: Soil	Re-cruit	Return	After rains: Water: Soil	Re-cruit	Return	Honey water: Soil	Re-cruit	Return
0.61	+	+	0	+	+	+	+	+	0	+	+	+
1.22	+	+	0	+	+	+	+	+	0	+	+	+
1.83	+	+	0	+	+	+	0	+	0	+	+	+
2.13	+	+	0	+	+	+	0	0	0	+	+	+
2.44	0	0	0	+	+	+	0	0	0	+	+	+
2.74	0	+	0	+	+	+	0	0	0	+	+	+
3.05	0	0	0	+	+	+	0	0	0	+	+	+
3.66	+[a]	0	0	+	+	+	0	0	0	+	+	+
4.27	0	0	0	+	+	+	0	0	0	0[b]	0	0
4.88	0	0	0	0[c]	0	0	0	0	0	0[c]	0	0
6.1	+[d]	+	0	+	+	+	0	0	0	0[c]	0	0
6.71	0	0	0	+	+	0[e]	0	0	0	+	+	+
9.15	0	0	0	+	+	+	0	0	0	+	+	+
12.2	0	0	0	+	+	+	0	0	0	+	+	+
15.24	0	0	0	+	+	+	0	0	0	+	+	+

[a] Placed 1 m from honey water, 6 pebbles dropped in.
[b] Undiscovered.
[c] *Camponotus* prevented access.
[d] 5 pebbles dropped in.
[e] *Camponotus* prevented return.

they observed may not have been tool use but simply a response to any moist substance.

With but few exceptions soil-dropping and recruitment to honey water, and return to the nest with the soil, was observed in both dry and wet seasons up to 15.24 m from the nest. Unless hindered by a wall of feeding ants surrounding the petri dish (many drank for long periods, up to 45 min), soil-dropping occurred shortly after discovery. At times, ants would crawl over the backs of those feeding in order to drop soil into the honey water. Even when recruitment was not heavy (sometimes as many as 60 ants would recruit to honey water within 30 min) soil-dropping was steadily pursued. Within 3 to 4 hr, petri dishes were filled with enough soil to soak up all the liquid. By dawn most of the soil would be gone and a trickle of ants could still be seen bearing pebbles and chunks of sticky sand back to their nests. (It was noted that where *Camponotus* prevented *N. albisetosus* from access to honey water, *Camponotus* did not drop soil into the liquid but fed from it and patrolled nearby). This finding differs with Fowler's (1982) study in which from 60–96 percent of the tools were not recovered. The colonies he chose may have been smaller than mine, with less of a demand for sugar.

Results from the field studies make it evident that, beyond a certain distance from the nest, soil-dropping is not simply a general response to any liquid. Foragers were selective. Within 2.13 m of the nest, however, the results were not so clear. Given the laboratory ants' behavior of dropping sand in water spilled into their nest, and given that in the field ants drop soil into water from 0.61 to 2.13 m from their nests, but with diminishing intensity as the water approaches 2 m, liquid close to the nest seems to pose a threat. A small puddle of rainwater, for instance, may become larger with more rain and eventually flow into the nest entrance. Levelling surrounding depressions indicated by small puddles may prove adaptive for nest protection. Wheeler's (1910) conjecture about the behavior evolving from a response to nest threatening liquid seems to be reasonable.

Under crowded laboratory conditions, for example when placed in a single box that serves as both nest and foraging space, many ant species, including *N. albisetosus,* will drop debris from their midden piles into honey water. Though at first glance it seems as if they are rejecting the honey water, this may be no more than a response to a nest-threatening liquid by using the closest material available. In laboratory nests, even those with foraging arenas, the debris is often not fed on for many days if at all after it has been dropped in the honey water. This is in agreement with Fowler's (1982) finding that most tools are not recovered. Unfortunately, distances from the nest are not given in his study. Further research will have to be done examining the percentage of soil retrieved with increasing distance from the nest.

Since, in the field, the soil-dropping response continued only toward the honey water as the two liquids were placed increasingly farther from the nests, it seems apparent that nest protection ceases to be a possible reason for soil-dropping behavior beyond a certain distance from the nest. The argument of chance has now been made less tenable. That is, beyond 2.13 m it is not the case that the ants are responding generally to a moist substance only to find that the soil which they drop into it becomes laden with sugar, after which they take it back to their nests. Here a better case for tool use can be made.

While the Fellers and Fellers (1976) study demonstrated the greater efficiency of food retrieval by tool use when compared with internal transport their conclusions about competition, as well as Fowler's (1982), must be considered cautiously. Their studies will have to be replicated at greater distances from the nest. Further, experimental artifact, though it seems unlikely, cannot be overlooked. Though the Fellers (1976) state that *Aphaenogaster* puts tools on squashed spiders, they do not say whether the workers retrieved the tools to the nest. I have observed *N. albisetosus* placing soil on a lizard squashed by a car, but not retrieving the soil to their nest. During two summers of studying these ants in the field, I have never observed a natural occurrence of tool use for food retrieval.

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